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ART. XVII.—*The Graptolite Succession of Bendigo East, with suggested Zoning.*

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I. Introduction.

Attention was directed to the Bendigo East area by the discovery some years ago of high Darriwilian graptolite beds hitherto unknown from that part of Victoria. The existence of a definite and sharp boundary between these high beds and the lower beds of the Bendigo Gold-field has been demonstrated(1), and field work has been continued to ascertain whether any light could be thrown on the succession of Darriwilian graptolites above the zone of *Diplograptus* (*Glyptograptus*) *austrodentatus* (zone D2). The present paper is an account of this work.

II. Acknowledgments.

The field work in the northern half of the area, as far south as Strathfieldsaye, was carried out by the writer. In Strathfieldsaye his work and that of J. J. Caldwell of the Geological Survey of Victoria overlapped. In Sedgwick and the parishes east and west of it the present work is based on Caldwell's survey. Through the kindness of the Director of the Geological Survey (Mr. W. Baragwanath) the writer was able to study most of Caldwell's graptolite collections, and though these were rarely complete enough for detailed work they indicated the critical localities which were then visited and studied in detail. Except for the beds west of the Whitelaw fault in Sedgwick, for which R. A. Keble's identifications have been accepted, practically all important parts of the district have been visited often with Mr. D. E. Thomas of the Geological Survey or with Mr. P. Tilson (Echuca). Great assistance has been given by the officers of the Mines Department, both in Melbourne and at the Bendigo Mines Office—the latter at first under the late H. S. Whitelaw and then under Mr. W. Kingston—while the details given above will show the writer's indebtedness to Mr. J. J. Caldwell. For the re-drawing of the map thanks are due to Mr. W. Bennett of the Draughting Branch of the Mines Department.

III. Scope of the Survey.

The area discussed is roughly a rectangle measuring about 22 miles from north to south and 8 miles from east to west. It includes the parishes of Wellsford, Strathfieldsaye, and Sedgwick, portions of the two northern parishes, Huntly and Bagshot, and the edges only of the western and eastern parishes, Sandhurst, Mandurang, Axedale, and Eppalock. All parts of the 180 square miles have not been treated in equal detail, attention being concentrated on the Darriwilian beds.

IV. Physiography.

The whole of the area shows mature topography. There are no permanent streams except the Axe and Bendigo Creeks. The northern part is within the basin of Bendigo Creek, but in the centre and south the drainage of Sedgwick, Strathfieldsaye, and the southern part of Wellsford finds its way to the Campaspe River through Axe Creek and its tributaries. The general slope is to the north-east, the divide between the two drainage systems mentioned being almost unrecognizable in the field. Heights above sea level decrease from about 1,200 feet on the northern slopes of the Mount Alexander granodiorite massif to less than 500 feet in the north. The gentle slopes and creek flats provide rather poor grazing and agricultural land, and much of the poorer land, especially on the low ridges, is included in forest reserves, settlement being restricted mainly to narrow strips along the watercourses. In Wellsford there are few exposures of bed-rock, though numerous fragments of ironstone (limonite) litter the surface. There are no roads other than innumerable dray-tracks, and practically no mining excavations. In such an area search for graptolites is disheartening work, but fortunately the few fossiliferous outcrops discovered were so spaced as to give some idea of the general structure though details are not ascertainable.

In Strathfieldsaye and Sedgwick occasional shallow road cuttings, small watercourses, the Emu Creek No. 2 water-race, and the Bendigo-Heathcote railway provide most of the fossiliferous outcrops.

V. General Geology.

The bed-rock of the district consists of Lower Ordovician sandstones and shales and may be divided into two unequal parts (Fig. 3)—Lancefieldian, Bendigonian, and Castlemainian west of the Whitelaw Fault, and younger rocks, mostly Darriwilian, east of the Fault, though these descend in normal succession to the east and, partly outside the mapped area, Lancefieldian is also reached in the east. An important feature of the beds east of the Fault is the extensive development of beds above the middle Darriwilian (D2 and higher). This feature gives the district

its special interest. The general strike of the Ordovician rocks is in most places 20° or more west of north, but local strikes of north-west or even almost east and west may be noted. The limited nature of fossiliferous rock exposures, together with close folding and pronounced cleavage, makes the working out of detailed structure impracticable at present.

VI. Distribution of the Graptolite Series.

(A) LANCEFIELDIAN.

Caldwell's survey demonstrated that the belt of Lancefieldian-Bendigonian which abuts on the Whitelaw Fault east and north of Bendigo can be traced right to the granite in the south of Sedgwick. It is uncertain whether the beds along the Fault in the southern part of the district are Lancefieldian or Bendigonian. No fossils were found sufficiently near the fault-line to settle the question. Caldwell shows the Lancefieldian as a narrow strip right along the fault-line. My own opinion is that the Lancefieldian beds narrow to the south and do not extend much further south than the southern boundary of Strathfieldsaye. In Sedgwick, if this is so, the Fault separates Darriwilian and Bendigonian. This opinion is partly based on the discovery of a slab showing *Tetragraptus fruticosus* along the Emu Creek water-race east of the south-west corner of Strathfieldsaye. Apart from this question of its relationship to the Whitelaw Fault, the western Lancefieldian belt does not appear to possess any features of special interest.

Caldwell also proved the existence of a wide belt of Lancefieldian to the east of the mapped area. This extends far east of Axedale. Only its north-western extension in the north of the parish of Axedale falls within the map. The relationship of this north-eastern area to the younger beds cannot be regarded as satisfactorily settled. Lancefieldian graptolites have been found at four rather widely separated outcrops. In the north-east of Wellsford, the Yankee Creek Gold-field occupies a narrow belt with the abnormal strike of N. $55-60^{\circ}$ W. No fossils were obtained near the old workings, but the spoil-heaps show that thin coal-black bands occur among lighter-coloured sandstones and shales. These carbonaceous partings are badly cleaved and are now so badly weathered that at a touch they fall to powder. Their occurrence is suggestive of Lancefieldian, but the evidence is inconclusive since similar thin bands yield Bendigonian graptolites at Brett's Freehold, west of Bagshot railway station. These beds strike towards more meridional lower Castlemainian (C5) beds further west. Whether they ultimately are shown to be Bendigonian or Lancefieldian, faulting has probably been responsible for their abnormal features. Whitelaw(2) noted a fault which shifted the strata near the shafts 200 feet to the east, and much more extensive faulting is probable but unproved.

(B) BENDIGONIAN.

In the west of the mapped area the Lancefieldian beds are succeeded by the Bendigonian series in normal ascending order. This may be accounted for by presuming a southerly pitch in this part of the area, in accordance with the general observations of pitch in the southern portion of the Bendigo Gold-field. In the north-east the Lancefieldian is also bordered by a narrow belt of Bendigonian. Its narrowness may be the result of faulting as has been suggested above.

Bendigonian beds are more widespread in the north, definite Bendigonian graptolites having been found at Brett's Freehold, and also some distance east of Bagshot railway station. Whether these two outcrops are part of a continuous area is uncertain.

In Axedale and Eppalock the Castlemainian beds which succeed the Darriwilian on the east are in turn succeeded by Bendigonian.

(C) CASTLEMAINIAN.

In the south of Mandurang and the south-west of Sedgwick the Bendigonian beds give place to lower Castlemainian. This is the normal succession, which is also found in the west of Axedale and Eppalock.

In the north of the district a rather extensive area of upper Castlemainian occurs in the east of Huntly and the south of Bagshot, graptolites of this horizon being rather common in material from the spoil-heaps of shafts along the course of the Huntly Deep Lead. Most of the localities yield upper Castlemainian graptolites, but at least two show middle Castlemainian forms. These beds come in their normal place between Bendigonian and Darriwilian. One interesting feature was a bed at Huntly, which in both lithology and graptolite content was practically indistinguishable from the type C2 locality at Victoria Gully, Castlemaine.

A continuation of the Castlemainian belt runs through the east of Wellsford. *Didymograptus proto-bifidus* was obtained from small fragments of shale at two places along Yankee Creek, and *Isograptus caduceus* var. *victoriae* still further south. West of this last outcrop the presence of *Isograptus caduceus* var. *maximodivergens*, almost in the centre of the parish of Wellsford, indicated either a high Castlemainian or a low Darriwilian horizon. This is the Castlemainian belt which has already been mentioned as striking across the continuation of the Axedale-Yankee Creek Lancefieldian.

(D) DARRIWILIAN.

The Darriwilian beds, both from their extent and from their special features, are the most interesting in the district. The whole of the central portion of the map from north to south is included in this belt. The Whitelaw Fault crosses the southern

boundary of the parish of Huntly and runs east of south to the Mount Alexander massif in the south of Sedgwick. Darriwilian beds border it on the east for the whole distance. They are succeeded on the east by a continuous belt of Castlemainian. These Darriwilian beds will be discussed in a later section of this paper.

VII. Zoning of the Darriwilian Series.

Since the Darriwilian zones were outlined in 1916(3) the succession of beds as high as the D2 zone (*Diplograptus austro-dentatus*) has been tested in many parts of Victoria. With minor differences, probably due to passage-beds and locally abnormal ranges, the series has been described from Ingliston by Ripper(4) and from Lancefield by D. E. Thomas (personal communication).

The base of the Darriwilian is marked by the incoming in force of *Oncograptus upsilon* T. S. Hall, and the first appearance of *Trigonograptus* and *Didymograptus v-deflexus* H. and K. In beds which are stratigraphically closely connected with the upper Castlemainian the typical form of *Oncograptus upsilon* is common. *Oncograptus upsilon* var. *biangulata* seems to come in later, but passage-beds between D5 and D4 may be expected in any locality where the succession is shown in great detail. Later *Cardiograptus morsus* H. and K. appears. A typical assemblage from a D5 outcrop might include:—

- Isograptus caduceus, var. maximo-divergens, Harris var.
- " var. divergens, Harris var.
- " manubriatus (T.S.H.).
- " hastatus Harris.
- " forcipiformis (Rued.).
- " dumosus Harris.
- Skiagraptus gnomonicus (H. and K.).
- Oncograptus upsilon T.S.H.
- " var. biangulata, H. and K. var.
- Didymograptus v-deflexus H. and K.
- " uniformis E. and W.
- Macandrograptus tau Harris.
- ? Cryptograptus sp.
- Trigonograptus ensiformis J. Hall.
- Phyllograptus sp.
- Dichograptus octobrachiatus J. Hall.
- Goniograptus speciosus T.S.H.
- Tetragraptus quadribrachiatus J. Hall.
- " serra Brong. (normal and also abnormally large variety).
- " headi J. Hall.

This list is incomplete as there are many undescribed species. The common basis of the lower Darriwilian zones (D5, D4, D3) is shown by a comparison of this list with an assemblage from either of the two higher zones(4). Advance is shown by the

incoming of *Cardiograptus morsus* in D4 and its usual survival beyond *Oncograptus* into D3, but the three beds form a stage in which the only important distinction is the degree of development of the Isograptidae as represented by *Oncograptus* and *Cardiograptus*. Even this distinction cannot always be made, though sometimes the dividing line is surprisingly sharp. Noting this we are forced to the conclusion, corroborated by the evidence of the Isograptidae themselves, that these zones represent a shorter time- or developmental-interval than is the average for other zones. The Isograptidae, as it were, shot ahead of their contemporary species. The Australian graptolite succession is more elaborate than other Lower Ordovician successions and its details are emphasized, especially when compared with a highly condensed succession such as that of the classic Point Lewis section. Another point to be emphasized here is that the general character of an assemblage must be taken into account, and not the mere occurrence of a single "zonal" graptolite. *Oncograptus* and *Cardiograptus* are found rarely but definitely in assemblages which undoubtedly represent higher zones than D4 or D3. In the same way occasional specimens of *Diplograptus* may turn up—and may be expected to occur—on horizons lower than those characterized by this genus.

VIII. Incoming of the Diplograptidae.

With the zone above D3 a distinct stage is reached leading to the Upper Ordovician—the incoming in force of the Diplograptidae. Three of the important trends of evolution followed by the graptolites are (i) stipe reduction, (ii) growth-direction change, and (iii) thecal elaboration. Diplograptus marks an important stage in each of these, and the suddenness of its development in Victoria is specially noteworthy, though probably more detailed work will tend to show that its entry is not as dramatic as it now appears to be. It is doubtful if many of the records of *Diplograptus* below the D2 zone are reliable. The forms on which the records are based are probably referable to other genera, or at any rate are not typical *Diplograpti*, though they may be forerunners. Such forms appear in C2, but are rare, and are even rarer in C1. Since *Diplograptus* is so common in D2, representatives may be expected in zones D5-D3, and though they have not yet been recognized, the Bendigo East survey leads one to believe that they occur. In the D2 zone we have a sudden outburst of the genus. Not only is *Diplograptus austrodentatus* the commonest graptolite of the zone, but it often outnumbered all other species so as to give a distinct character to the horizon. Many D4 and D3 species persist and some higher forms enter, but all are subordinate to *Diplograptus austrodentatus*, which is as typical of the zone as *I. caduceus* var. *victoriæ* is of zone C2.

The following actual assemblage is given as typical of the horizon:—

- Diplograptus* (*Glyptograptus*) *austrodentatus* H. and K. (v.c.).
- Isograptus caduceus* var. *divergens*, Harris var. (v.c.).
- " *forcipiformis* (Rued.).
- " *hastatus* Harris.
- " *dumosus* Harris.
- Cardiograptus morsus* (r) H. and K.
- Skiagraptus gnomonicus* (r) (H. and K.).
- Didymograptus v-deflexus* H. and K.
- Tetragraptus serra* Brong. (c).
- Phyllograptus* sp. (probably *P. anna* J. Hall) (v.c.).
- Trigonograptus ensiformis* J. Hall.
- Dichograptus* sp.

Though the Darriwilian succession as high as D2 is well established, few localities show a continuous section from D3 to D2. Ripper(4) reports that at Ingliston the succession is normal, but cannot be continuously traced. The zone is well represented in the Brisbane Ranges south of the area studied by Ripper, and observations made there by Thomas and the writer make it certain that *Diplograptus austrodentatus* enters with *Cardiograptus* and even with *Oncograptus* and ranges beyond these forms. The original locality for the zone of D2 was the Guildford-Strangways road west of Guildford(2), and here the succession from D3 to D2 is clear, *Diplograptus austrodentatus* and *Cardiograptus morsus* occurring at first together and being succeeded by beds from which *Cardiograptus morsus* is absent. (The *D. cf. angustifolius* mentioned was later described as *D. austrodentatus*). Thomas has since confirmed this observation as the result of his examination of the area north of the Loddon River in the same district. The normal succession also is found along the Gisborne Creek near the Gisborne gold-mine at Bullengarook, where D2 beds occur west of D3 beds in a succession which, traced from the east, is ascending normally to this horizon. Details of folding have not yet been worked out here. D2 beds are also extensively developed in the Brisbane Ranges and at Steiglitz, but no detailed work has been done in either area apart from an unpublished survey of Steiglitz by W. H. Ferguson, late of the Geological Survey. T. S. Hall identified many of Ferguson's graptolites(6), but in the light of later work the determinations both published and unpublished stand in need of revision. The writer has also recognized *Diplograptus austrodentatus* in a small collection from Sebastian (between Bendigo and Raywood) shown him by W. Kingston of the Bendigo Mines Office.

IX. Typical Sections.

(1) HUNTLY-BAGSHOT.

This section is taken across the north of the mapped area. As stated above, the Whitelaw Fault crosses the west of the parish, running diagonally through Section XXIX. In the south of this section the parish plan shows a "Stone and Gravel Reserve." This derives its local name, Ironstone Hill, from the capping of cemented gravel now partly removed by mining operations or for use as road-making material, and is on the western side of the fault-line. Immediately to the north-east the continuation of these gravels lies below the surface and they have been mined by shallow shafts, the spoil-heaps of which yield abundant upper Darriwilian graptolites. The difference of level is interesting as it is probably the result of post-Pliocene movement along the line of the Whitelaw Fault. Examples of later movement along fault-lines which are very old are found elsewhere in this district and in other parts of Victoria (7). Further to the south-east the similar gravel outcrops of the White Hills end rather abruptly at the fault-line and are succeeded on the north by buried gravels. A search of old mining records shows that the difference of level was observed nearly forty years ago. In 1898 James Stirling reported (8), "Mr. Mining Surveyor O'Dwyer has stated that on the Huntly Lead south of the White Hills the sinking is shallow—from 10-25 feet deep—but north it suddenly drops to 50 feet and at lower levels 70 feet." A similar abrupt change of level is recorded west of Sebastian where, although the only recorded graptolites are Darriwilian (D5 and D2), there is quite possibly a fault comparable with the Whitelaw Fault. Repeated movement along the lines of major faults is a widely recognized phenomenon. An interesting observation is that the floor of the Huntly Deep Lead beyond Brett's Freehold rises 27 feet in five miles instead of having the usual fall (9).

Practically every spoil-heap in the northern part of Section XXIX. Huntly (now used as a sewerage farm for the city of Bendigo) yields upper Darriwilian graptolites. A good collection, though in very soft, weathered shale, can be gathered in Allot. 8. Owing to the troublesome cleavage at many localities and our total ignorance of the folding of the bed-rock, detailed zoning is difficult and has not been attempted. The underlying rocks are probably closely folded, and beds as low as D2 may be present, though they have not been noticed.

East of the Bendigo Creek the spoil-heaps give a fairly complete section. Just outside the city area, between the Echuca-road and railway, upper Darriwilian graptolites are common, and this belt may be traced as far as the north-east of Epsom. The beds are characterized by the common occurrence of *Amplexograptus* and *Didymograptus nodosus* Harris, which are associated

with other characteristic forms such as *Lasiograptus proteus* Harris and Thomas and *Cardiograptus crawfordi* Harris. These beds occur west of the Bendigo Pottery at Epsom (within the belt-defined above), but a few chains north of the Pottery a somewhat different facies is observed (Sect. XII., Ascot.) Here several spoil-heaps show different *Diplograpti*, chiefly *Diplograptus intersitus* H. and T., and a different *Didymograptus*, *D. compressus* H. and T. The commonest *Lasiograptus* is also distinct—*Lasiograptus etheridgei* Harris. This belt may be traced north-westerly through Sections IV. and V., Huntly. Still proceeding east from Epsom *Diplograptus austrodentatus* makes its appearance in Section VIII., Huntly, and on the Sandy Creek-road near Allot. 7 of Section I. This has not been traced further north, though it is very likely that an exhaustive search would show it. In Section XX. D3 beds occur, though only a few graptolites were found, and then in Section XVIII., further north-east there are several occurrences of D4 and D5 beds. The last of these are just east of the Echuca-road north-east of Huntly township, but similar beds cross the railway at Huntly R.S. East of the Echuca-road the spoil-heaps in Section XIX., Huntly, and Section XII., Bagshot, give upper Castlemainian graptolites (C1 and C2), though there is an isolated record of D5 in Allot. 4, Section XII. C1 beds outcrop south of the railway on the Sandy Creek-road, and slightly lower beds are found not far from them. Along Yankee Creek, on the southerly continuation of the strike of these beds, the writer found *Didymograptus protobifidus* Elles, and then near Bagshot railway station, *Tetragraptus fruticosus* J. Hall, and other Bendigonian forms. The immediate purpose of this paper does not need the extension of this section further east, though this is the locality where the next beds to the east are Lancefieldian, apparently striking right into the Castlemainian.

For the present it is sufficient to sum up that—

- (a) as low as the Castlemainian the succession is apparently normally sinking to the east.
- (b) above the D2 beds is a bed characterized by *Diplograptus intersitus* and *Didymograptus compressus*.
- (c) above (i.e., further west than this) is a bed characterized by *Diplograptus* (?*Mesograptus*) *decoratus* H. and T. (allied to *D. coelatus* Lapworth), *Amplexograptus*, and *Didymograptus nodosus* Harris.

This succession is seemingly in normal order, and attention is directed to it, since it seems to hold elsewhere in the district and will be used as a suggested zoning of these high Darriwilian beds. This section, although described first, was the last to be worked out in the field, when it was found that the boundaries provisionally fixed on the evidence of sections further south did not need adjustment.

(II.) MCIVOR-ROAD.

South of the Huntly-Bagshot section just described is the unsatisfactory area of Wellsford. The next line of section is along the Bendigo-Heathcote railway and the almost parallel road (McIvor-road). This gave a succession descending from upper Darriwilian to Castlemainian and even lower and seemed so promising that attention was devoted to it first. As in most sections, exposures are not continuous, but the gradually descending order generally as one went east from the Whitelaw Fault was soon evident. Local interruption and repetition of beds was to be expected, but the section proved to be unexpectedly complete. The two zones mentioned in the account of the more northern section as being above D2 were recognizable—in fact, it was along this section that they were first recognized—as well as probable passage-beds. Caldwell's survey enabled similar beds to be located further south, and from some of these, as well as from others already known to the writer, fairly extensive collections were made.

From the Whitelaw Fault to the crossing of road and railway at 97 miles 36 chains, a distance of about $1\frac{1}{2}$ miles, there are numerous graptolite beds, all above the zone D2. As stated, two distinct zones could be noted, though there are minor differences between beds even of the same general zone. Some of these differences may later prove to be of stratigraphical value, or they may be due to the tendency of forms on this horizon to be abundant in some narrow bands and almost absent from bands quite close by.

The first locality from which a good collection was made is opposite the junction with the McIvor-road of a road from the north-east, about 30 chains east of the Whitelaw Fault. Similar beds occur near the north-west corner of the parish of Strathfieldsaye (loc. 209)*. A good collection can, with some trouble, be made at either outcrop, but the horizon—the zone of *Didymograptus nodosus*—is represented by better material south of Strathfieldsaye township (loc. 164) and elsewhere, and only its horizon need be noted. The second assemblage—the zone of *Diplograptus intersitus*—occurs nearer the crossing (locs. 210, 211) and in a fragmentary state at the crossing itself. All these beds extend through to the railway line a little distance to the north. The loc. 210 assemblage is also better represented further south (locs. 196, 201, 298). Along this section then, as elsewhere, two assemblages above the D2 zone may be noted.

Proceeding east from the crossing the next fossiliferous band was found near the 97 mile post—the zone of *Diplograptus austrodentatus* (D2)—and this is repeated further east. Near the 96 m. 8 ch. crossing, a *Diplograptus intersitus* band crosses

* For convenience Caldwell's field numbers are used hereafter for all localities which are marked on his plans.

the railway. If the normal descending order had been maintained, this bed should have been below the D2 zone, but there is little doubt that it is rather on the same horizon as loc. 210.

East of the 96 m. 8 ch. crossing a typical D4 outcrop is found, but this need not be considered in detail. Intervening beds may be hidden, but it is probable that the zones of D3 and D2 are missing from this part of the area. More than a mile of unfavourable beds or shallow cuttings separates this occurrence from the next to the east—beds of almost the same horizon in cuttings between Allots. 1 and 2, Section XVII., Strathfieldsaye. Caldwell's survey shows that still further east Castlemainian beds occur, and then, nearer Axedale, Bendigonian and Lancefieldian.

(III.) STRATHFIELDSAYE.

The main Country Roads Board road through Strathfieldsaye to Eppalock has few cuttings, but a section can be obtained roughly along it. The Whitelaw Fault crosses the road almost on the western boundary of the parish of Strathfieldsaye, with Lancefieldian beds (loc. 230) west of it. The beds nearest to it, but east of it, are not well shown, but *Didymograptus nodosus* has been recorded from them. The next outcrop (loc. 196) yields abundant material which shows graptolites clearly when "green," but less distinctly when dry. *Diplograptus intersitus* and *Didymograptus compressus*, the zonal fossils, are very common. A few chains to the east, *Didymograptus nodosus* occurs, but the material is fragmentary. The variety of *Didymograptus nodosus* is less robust than the typical zonal form and the bed is probably transitional.

North of the township of Strathfieldsaye a very shallow water-race yields a limited amount of shale with indistinct graptolites. *Diplograptus intersitus* occurs here also. Badly cleaved graptolite shale (loc. 244) is also found in Allot. 41 about a mile east of the last outcrop mentioned. *Isograptus raduceus* occurs in association with poorly-preserved *Diplograpti*, probably *D. austrodentatus*, marking the southern extension of the D2 zone noted on the railway to the north. Still farther east a group of outcrops on the Axe Creek (locs. 159, 160) yield *Oncograptus upsilon biangulata*, *Cardiograptus morsus*, and *Didymograptus v-deflexus*, and can be correlated also with the similar beds on the railway. Before the parish boundary is reached the horizon is Castlemainian (locs. 226, 229), conclusive evidence being supplied by outcrops north and south of the road.

(IV.) EMU CREEK (Fig. 1).

This section is taken across the south of the parish of Strathfieldsaye. Bendigonian beds are shown in the south-west corner of the parish (locs. 179, 180, 181) on the west side of the Whitelaw Fault. Nearer the fault along the Emu Creek No. 2

water-race the writer found a single specimen of *Tetragraptus fruticosus*, and it is doubtful whether the Lancefieldian belt which lies along the west of the fault-line farther north extends as far south as this. It may pitch underfoot bringing Bendigonian beds up against the Darriwilian. Caldwell, however, shows a narrow strip of Lancefieldian right along the line. Once the fault-line is crossed there is an almost continuous section of upper Darriwilian along the water-race, which here cuts obliquely across the strike of the bed-rock. Probably the best outcrop of the *Didymograptus nodosus* zone in the district is on the water-race, but north of this section (loc. 164). Along the race most of the fossiliferous bands seem to belong to passage beds between the typical zones of *Didymograptus nodosus* and *Diplograptus intersitus*, but for the present are grouped with either one or the other. A locality such as 176 on the Sedgwick-road provides a good example. Here, *Diplograptus decoratus* is very common, associated with the less robust variety of *Didymograptus nodosus* and *Lasiograptus etheridgei*, the last-named

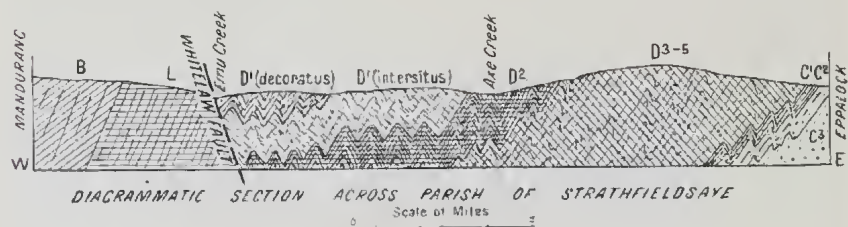


FIG. 1.

species being usually associated with the *Diplograptus intersitus* zone in other parts of the district. This outcrop is included in the *D. nodosus* zone. Farther east, as at loc. 173, *Diplograptus intersitus* is found, but the variety of *Didymograptus compressus* associated with it shows some affinities with *Didymograptus nodosus*. It is remarkable that though the two mentioned species of *Didymograptus* are easily distinguished when typically developed, specimens are often found which seem to lie between them.

After the race is left near the Emu Creek State School, an outcrop of the *Diplograptus decoratus*-*Didymograptus nodosus* zone is found (loc. 167) and then, after beds on the *Diplograptus intersitus* horizon (loc. 203), *Diplograptus austrodentatus* appears in the north-east corner of Allot. 26, Section III., Strathfieldsaye, indicating that the D2 zone has been reached, though the presence of an occasional *Diplograptus intersitus* (loc. 169) is an indication that these beds are well up in the D2 zone. Similar, or slightly lower, beds are found on the other side of Axe Creek (loc. 198), though *Diplograptus intersitus* is well represented in

beds a little to the west of this last locality (locs. 170, 202, 203). A mile east of loc. 198 the record of *Oncograptus* (loc. 205) shows that lower Darriwilian has been reached, and near the eastern boundary of the parish, upper and middle Castlemainian beds occur, C1 beds outcropping on the road between Sections VII. and VIII. about 150 yards west of the boundary and being separated by less than 50 feet from C2 beds. In the parish of Eppalock the succession is continued through middle and lower Castlemainian to Bendigonian and Lancefieldian.

(v.) SEDGWICK.

Sedgwick is the parish south of Strathfieldsaye. Little attention was given to beds west of the Whitelaw Fault since Keble's identifications from Caldwell's collections showed that Bendigonian beds near the fault were succeeded regularly on the west by lower Castlemainian (C5). No Lancefieldian graptolites have been recorded from the parish, though Caldwell shows a narrow strip of Lancefieldian right along the Whitelaw Fault.

In the eastern half of the parish the chief feature is the extensive development of the zone of *Diplograptus austrodentatus* (D2) and the zone of *Diplograptus intersitus*. No direct section was obtained across the area east of the fault-line, but a composite section can be made which gives a good idea of the structure. The first locality (loc. 300), is near the Sedgwick-road in the north of the parish. Here the *Diplograptus decoratus*-*Didymograptus nodosus* zone is well represented. Farther south loc. 303 on Axe Creek yielded *Diplograpti* probably of the same zone, and certainly higher than the zone of *Diplograptus intersitus*. These outcrops show that a narrow belt of the *Didymograptus nodosus* zone extends along the fault line.

The next group of localities lies south-east of loc. 300. Here a number of outcrops (locs. 298, 283, 284, 285) yield *Diplograptus intersitus* in profusion, the associated *Didymograptus*, *D. compressus*, being less common but occasionally forming tangled masses. The most northerly band (loc. 299) contains more rarely *Didymograptus nodosus*, and more commonly the larger *Diplograpti*, and is probably just above the *Diplograptus intersitus* horizon. East of Axe Creek *Diplograptus austrodentatus* is well represented (locs. 309, 313, 314) though *Diplograptus intersitus* is also present. Loc. 314 is particularly interesting, as not only do both these *Diplograpti* occur, but *Oncograptus upsilon* is sparingly represented, an example of survival which has already been commented on. At loc. 310 farther south is a typical outcrop of the *Diplograptus austrodentatus* zone, and here and at loc. 314 forms are occasionally found preserved as pseudomorphs in limonite or as moulds when the crumbling filling has fallen out. At both localities also a small species of *Phyllograptus* (? *P. anna*) is not uncommon, though this genus is more common on higher and lower horizons

elsewhere. *Diplograptus intersitus* occurs as far south as Section XVI. (loc. 325) and east of the D2 belt, near the eastern boundary of the parish lower Darriwilian beds come in, typically represented by loc. 316. The survey has not been extended eastward into Lyell, but indistinct graptolites obtained about a mile within this parish appeared to be of lower Castlemainian age and lower Castlemainian and Bendigonian graptolites are found in the south of the parish.

X. The Upper Darriwilian Succession.

It will be seen that this district provides details of the D2-D1 succession not yet found elsewhere. The succession indicated by the development of the graptolites is corroborated by the field evidence. Commencing with *Diplograptus austrodentatus* we find this form the predominant graptolite at outcrops such as locs. 310, 313, and many outcrops in the south of the area, as also near the 97-mile post and elsewhere in the centre. Then at outcrops such as 169, 198, 309, and 314, although this form is one of the commonest graptolites, it is associated with *Diplograptus intersitus*. *Diplograptus intersitus* then characterizes a series of beds (locs. 196, 201, 210, 284, 298). It is then found associated with the larger *Diplograpti* such as *Diplograptus decoratus* (loc. 299) and finally these forms, mainly *Amplexograpti*, predominate, *D. intersitus* occurring only rarely (locs. 164, 176, and Section XXIX., Huntly).

Apart from the *Diplograpti* other forms also show progression. *Lasiograptus etheridgei* enters with *Diplograptus austrodentatus*, is common at some, but not all, beds with *Diplograptus intersitus* (it is rare at loc. 196), becomes one of the commonest graptolites in beds where *Diplograptus decoratus* is associated with the less rigid variety of *Didymograptus nodosus* (loc. 176), and finally is replaced by *Lasiograptus proteus* H. and T. (loc. 164, Section XXIX., Huntly). This latter species has a much less complete meshwork than *L. etheridgei* and in adult stages mimics *Glossograptus hincksii* with which it has probably been confused in some lists. *Glossograptus acanthus* E. and W. enters with *Diplograptus austrodentatus*, and is common with *Diplograptus intersitus*, but does not commonly range higher. *Diplograptus intersitus* is associated with a distinctive *Didymograptus* of restricted range (*Didymograptus compressus* H. and T.) This has at first a straight dorsal margin, but later forms are found in which this margin has become "corrugated" (loc. 173) and the appearance of the species approaches *Didymograptus nodosus*. *Didymograptus nodosus* itself appears to be preceded by a variety with initially narrow stipes resembling those of *D. compressus* (loc. 176, 197). Another graptolite typically restricted to the *D. intersitus* zone is *Pterograptus incertus* H. and T. *Cardiograptus crawfordi* is not characteristic of any bed below the zone of *D. intersitus*, but is found on this and higher horizons.

No zone higher than that of *Diplograptus decoratus*-*Didymograptus nodosus* has been found in this district, nor is the presence of any such zone indicated by the stratigraphy, but such a bed is known elsewhere in Victoria. Near the 8-mile stockyard on the Howqua River, eight miles upstream from the deserted township of Howqua (now commonly called "Fry's"), *Diplograptus* beds are found. More than one species of *Diplograptus* is present, but specimens showing thecal characters clearly are rare. One of the commonest forms is *Diplograptus* (*Glyptograptus*) *euglyphus* Lapw. With it are associated *Glossograptus hincksii*, *Pterograptus lyricus* K. and H., and *Isograptus oratus* (T. S. Hall). The same assemblage is found at the more accessible locality of Turner's Quarry, Mornington Peninsula (Allot. 27B, Bittern). This assemblage bears a very close resemblance to that of Ba 67 at the junction of Jackson's and Riddell's Creeks (Q.S. 6 S.E.) usually taken as the basal graptolite zone of the Upper Ordovician, and the identifications of New Zealand forms by Keble and Benson(10) show from the Cobb River in Nelson a closely related assemblage, probably between our Howqua and Ba 67 beds. The New Zealand forms are preserved in hard blue-black shale, but have a "frayed" appearance which makes comparison with our more clear-cut forms difficult especially in the case of *Diplograpti*; but the painstaking work of the authors quoted leaves no doubt as to the general resemblance (*ibid.*, p. 845, loc. 1231). There is hardly a form which does not occur at Turner's Quarry or Ba 67, or is not closely related to forms occurring there, but the general aspect of the *Diplograpti* seems to point to a rather closer resemblance to the Turner's Quarry beds than to those of the higher horizon. This is a case where an opinion is based on the general nature of the assemblages and on evidence which a faunal list cannot weigh. At present the writer's personal opinion is that the Cobb River beds may best be regarded as passage beds which, in a broad classification, would be included in the same zone as those from Turner's Quarry.

To complete the *Diplograptus* series the Ba 67 beds should be included as the uppermost zone. Immediately and conformably above them are beds containing *Dicellograptus sextans* J. Hall and *Dicranograptus brevicaulis* E. and W. with an assemblage otherwise the same as the lower horizon. These beds mark the incoming of the Dicranograptidae, the first really important stage after the incoming of the Diplograptidae. (Throughout this paper the earlier appearance of one of the Diplograptidae, *Trigonograptus*, has not been emphasized owing to the general rareness of specimens of this genus). Thomas and Keble(11) leave Ba 67 as the base of the Upper Ordovician, with which stratigraphically its relationship is very close, but we have no certain knowledge that elsewhere in Victoria, as for example

between Newham and Rochford, similar beds may not be found closely associated with typical D1 beds. Moreover, Keble has recorded from Mornington, north-east of Turner's Quarry, a bed which seems to be either equivalent to Ba 67 or a passage-bed leading to it. Unfortunately the outcrop is so limited that this information cannot be amplified.

XI. Zoning of the Darriwilian and Castlemainian in Victoria.

The erection of zones of *Diplograptus intersitus*, *Diplograptus decoratus*, and *Diplograptus euglyphus* from beds hitherto grouped as upper Darriwilian or D1 lessens the exactness of the index number. Since such numbers, though convenient for field use, do not of themselves convey any definite meaning, an attempt is now made to convert the present classification into one which will indicate the biological development of the graptolites selected as zonal fossils, it being kept in mind that a zonal fossil, like a zone number, is little more than a reference aid, the whole assemblage and relative abundance of forms being important factors.

The division of the Victorian graptolite succession into Lancefieldian, Bendigonian, Castlemainian, and Darriwilian series is due to T. S. Hall (12). The same pioneer worker used the term "zone" to include indifferently the "zone of *Tetragraptus caduceus*" (i.e., C.2), and the "zone of *Tetragraptus fruticosus*" (i.e., the whole Bendigonian series (13)), but it has long been evident that the division between any two series is not in any case more important than the division between some zones within the same series, while the local names are no longer descriptive since every series is represented in each of the serial districts except possibly at Darriwil. When Lancefieldian meant only the Mount William quarry assemblage, Bendigonian the typical beds of the Bendigo gold-field, and Darriwilian the isolated *Diplograptus* bed at Darriwil, the series could be regarded as distinct. Fig. 2 shows this diagrammatically, no attempt being made to represent the thickness of any zone or series.



Fig. 2.—Scope of Hall's scheme, 1899, shown by shaded portion. Present scope shown by full length of column.

With the extension of knowledge even in Hall's time the spaces in the succession were filled in, until when Hall's work was complete the only gaps were above the Castlemainian. It is not proposed to deal with the Bendigonian or Lancefieldian as they

lie outside the scope of the present paper, but since the tuning-fork *Didymograpti* in England are associated with what are Darriwilian forms in Victoria, a beginning will be made with them.

The incoming of *Didymograptus proto-bifidus* is locally sufficient to warrant the erection of a transition series between the *Tetragraptus fruticosus* series and the succeeding series of *Iso-graptus*. The *Didymograptus proto-bifidus* beds may be divided into a lower and an upper part, and if the predominance of one species is not considered sufficient for the constitution of a separate series the lower bed would be the uppermost zone of the *Tetragraptus fruticosus* series, while the upper (C5) would be the base of the *Iso-graptus* series. The present numbers B1 and C5 express this. Later work on the horizontal *Didymograpti* may make possible a more useful zoning as apart from *D. proto-bifidus* in C5, the C5 and C4 beds have no easily recognized zonal forms, *Iso-graptus caduceus* not becoming important usually till the C3 horizon is reached.

Iso-graptus caduceus then, entering with *D. proto-bifidus* in C5, becomes important in C3 and the Isograptidae then predominate as high as the middle Darriwilian (D3). The dividing line between C1 and D5 does not mark an important break, the chief difference being the stage of development of the Isograptidae as indicated by the incoming of *Oncograptus*, though new forms such as *Didymograptus v-deflexus* and *Trigonograptus* also appear first in D5. The *Oncograptus-Cardiograptus* (D4) and *Cardiograptus* (D3) zones are usually recognizable, carrying on the development of the Isograptidae, but the occasional survival of both *Oncograptus* and *Cardiograptus* to a higher horizon, though upsetting to any hard and fast zoning, is what might be expected and in the field is not usually disconcerting. The developmental period occupied by zones D5-D3 was probably relatively brief. The zones commencing with D2 (zone of *Diplograptus austro-orientatus*) mark an important advance and may be grouped as a *Diplograptus* series. Biologically this series should include all beds below that which marks the next important stage—the incoming of the Dicranograptidae. This would include in this series the Ba 67 bed. It is not necessary for the older serial names to be discarded for purposes of reference (in the field they are very useful), but the suggested scheme makes the basis of the succession clearer. An obvious classification would be to call the *Diplograptus* series Middle Ordovician, intermediate as these beds are in texture and life-content between the typical Lower and Upper Ordovician. This suggestion, first tentatively made in conversation by Thomas, has the disadvantage that in Britain the Middle Ordovician is characterized by *Nemagraptus*, *Dicellograptus* and *Climacograptus* (14), an assemblage corresponding with the lower zones of our Upper Ordovician.

The proposed *Diplograptus* series in outline is therefore as under:—

Diplograptus Series.

Zone of DIPLOGRAPTUS (GLYPTOGRAPTUS) TERETIUSCULUS (highest).

Typical locality—Ba 67 at junction of Riddell's and Jackson's Creeks (Q.S. 6 S.E.).

Characteristic assemblage:

- Diplograptus teretiusculus* (v.c.) His.
- " *euglyphus* (c) Lapw.
- Climacograptus riddellensis* (c) Harris.
- Cryptograptus tricornis* (c) Carr.
- Glossograptus hincksii* (c) Hopk.
- Retiograptus speciosus* (c) Harris.
- Isograptus caduceus*, var. *tenuis* (v.r.) Harris var.
- Didymograptus* (horizontal spp.) (c).
- Pterograptus lyricus* K. and H.

Zone of DIPLOGRAPTUS (GLYPTOGRAPTUS) EUGLYPHUS.

Typical localities—Turner's Quarry; 8-mile, Howqua River.

Characteristic assemblage:—

As above, except that *D. teretiusculus* has not been recognized with certainty, *Tetragraptus* is more common, and *Retiograptus speciosus* not yet recorded. *Isograptus ozatus* occurs at both the typical localities, though elsewhere it seems to be an Upper Ordovician form.

Zone of DIPLOGRAPTUS (? MESOGRAPTUS) DECORATUS (D. aff. COELATUS).

Typical localities—Loc. 164 Strathfieldsaye; loc. 300 Sedgwick; Allot. 8, Sect. XXIX. Huntly.

- Diplograptus* (? *Mesograptus*) *decoratus* (v.c.) H. and T.
- " (*Amplexograptus*) *confertus* (c) Lapw.
- " " *differtus* H. and T. (c).
- " " *modicellus* H. and T. (c locally).
- Cryptograptus schaeferi* Lapw.
- Lasiograptus proteus* H. and T.
- Isograptus forcipiformis* (Rued.).
- Cardiograptus crawfordi* Harris.
- Brachiograptus etaformis* H. and K.
- Trigonograptus ensiformis* J. Hall.
- Didymograptus nodosus* (v.c.) Harris.
- " *dubitatus* H. and T.
- " *cognatus* H. and T. (c).
- " *cuspidatus* Rued.
- " *acriculus* K and H.
- Atopograptus woodwardi* Harris.
- Phyllograptus nobilis* (v.c.) H. and K.
- Tetragraptus* spp.

In what are probably the lower beds of this zone, *D. decoratus*, *Didymograptus nodosus*, and *Lasiograptus etheridgei* are the commonest species as, e.g. at loc. 176 and north-west of Turner's Quarry. A similar assemblage, with *D. nodosus* very rare, is found at Woodend (Allots. 95-99) and at Newham (Sect. 20).

Zone of DIPLOGRAPTUS (GLYPTOGRAPTUS) INTERSITUS.

Typical localities—Locs. 196, 210 Strathfieldsaye; 298 Sedgwick.

- Diplograptus* (*Glyptograptus*) *intersitus* (v.c.) H. and T.
- Lasiograptus etheridgei* (v.c.) Harris.
- Isograptus forcipiformis* (Rued.).
- " *caduceus* varr.

Cardiograptus crawfordi (c) Harris.
Cryptograptus schaeferi Lapw.
Glossograptus acanthus E. and W.
Trigonograptus ensiformis J. Hall.
Didymograptus compressus (c) H. and T.
 spp.
Tetragraptus spp.
Pterograptus incertus (c) H. and T.
Phyllograptus sp.
Loganograptus cf. logani (v.r.).

Zone of *DIPLOGRAPTUS AUSTRUDENTATUS* (D2).

Typical localities—Loc. 310 Sedgwick; Guildford-Strangways Road; Brisbane Ranges.

Characteristic Assemblage. (See list on page 321).

Isograptus Series.

Zone of *CARDIOGRAPTUS MORSUS* (D3).
 Zone of *CARDIOGRAPTUS* and *ONCOGRAPTUS* (D4).
 Zone of *ONCOGRAPTUS* (D5).
 Zone of *ISOGRAPTUS CADUCEUS* varr. *MAXIMA* and *MAXIMO-DIVERGENS* (C1).
 Zone of *ISOGRAPTUS CADUCEUS* var. *VICTORIAE* (C2).
 Zone of *ISOGRAPTUS CADUCEUS* var. *LUNATA* (C3, C4).

Didymograptus proto-bifidus Passage Beds.

Zone of *DIDYMOGRAPTUS PROTO-BIFIDUS* and *ISOGRAPTUS CADUCEUS* varr. *PRIMULA* and *LUNATA* (C5).
 Zone of *DIDYMOGRAPTUS PROTO-BIFIDUS* and *TETRAGRAPTUS FRUTICOSUS* (B1).

Tetragraptus fruticosus Series.

(Bendigonian zones).

XII. Correlation.

The correlation of Victorian graptolite zones with those of the other side of the world lies outside the scope of the present paper, but the subject cannot be altogether neglected. There can be little doubt that, as stated in an earlier paper (5), the Victorian *Diplograptus* series is the equivalent of the Llanvirnian, and it is probable that more detailed work will increase rather than lessen the resemblances of the assemblages. It should be noted, however, that in England *Diplograptus* enters on a lower horizon and that in Victoria the tuning-fork *Didymograpti* are absent from the Darriwilian. In fact, whether our common Victorian dependent *Didymograptus* is *D. bifidus* Hall or *D. proto-bifidus* Elles, its associations are not the same here as in either Europe or America.

The correlation of lower zones is more difficult and the opinion is expressed that it would be well to delay a revision of the correlation until a detailed and systematic study has been made of Victorian horizontal *Didymograpti*. Our knowledge of these forms is at present very limited, partly because their zonal value has not been stressed, and partly because as a rule Victorian forms which otherwise resemble those of the old world have lower angles of thecal inclination, and the value to be attached

to this has not been decided. It is rare, as far as I have studied these forms, to find any with angles of over 35° , and the identity of even well-known forms such as *D. nitidus* and *D. nicholsoni* has not yet been definitely asserted.

XIII. Notes on the Map (Fig. 3.)

The map which accompanies this paper is intended chiefly to show the distribution in the Bendigo East district of the graptolite zones outlined. Fossiliferous outcrops are too scattered to enable it to represent detailed structure. It is probable that as faulting can be clearly demonstrated east and west of the mapped area (towards Heathcote and at Bendigo) it also affects the present area.

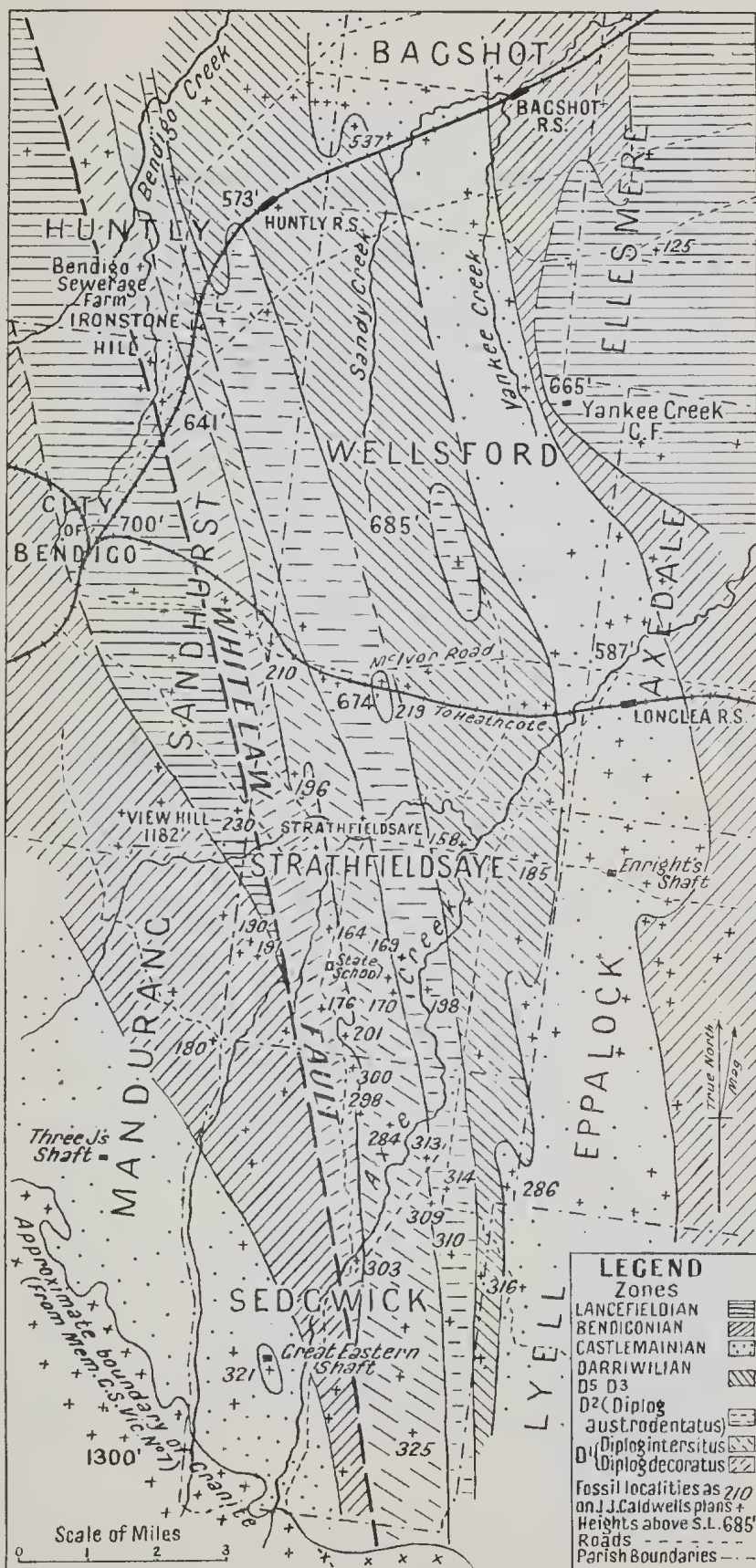
When the features marked on the map are shown on a larger scale, e.g., 2 inches to the mile, several interesting features, rather obscure on a smaller map, stand out.

(1) It is probable that the broad belts of Lancefieldian, Bendigonian, and Castlemainian west of the Whitelaw Fault enclose smaller areas or strips of one or other series. The detailed survey of the Bendigo Gold-field (15) shows that this is so in the central Bendigo area. If it is found not to be so south of Bendigo, the difference in folding may possibly be correlated with the less auriferous nature of the rocks in that direction.

(2) The belts of Darriwilian east of the fault are shown as long usually narrow strips, with some minor indentations in their outline due to pitch. It is certain that more detailed work will show that the number of indentations and inliers of other series is much greater than the present map indicates. With the increase of emphasis on assemblages of species and relative abundance rather than the mere occurrence of a "zonal" form, large collections are necessary for accurate zoning, especially when there is a tendency for species to be restricted locally to bands.

(3) The appearance of great width of the lower to middle Darriwilian in the parish of Wellsford may be partly due to lack of evidence to the contrary. Indefinite evidence of the presence of *Diplograptus austrodentatus* near the centre of the parish was obtained, but was insufficient to warrant alterations in the mapping. Here again, and in fact over the whole of this unsatisfactory parish, detailed work is much to be desired.

(4) The problem of the relationship of Lancefieldian to Bendigonian and Castlemainian in the north-east of the area has already been mentioned. A possible partial solution would be the placing of a fault running north and south almost along the western boundary of Eppalock and Axedale. This might help to account for the narrow strip of D3-D5 in Sedgwick, but as no positive evidence at all has yet been produced it does not seem wise to do more than suggest the possibility.



XIV. Index to Graptolite Localities.

Caldwell's
Field No.

- A.159. 28 chains west from south-east corner of Allot. 11, Sect. X., Strathfieldsaye (D5).
160. 23 chains west, 7 chains south from north-east corner of Allot. 12, Sect. X., Strathfieldsaye (D4).
164. Where water-race touches Emu Creek-road at south-east corner of Allot. 19, Sect. IV., Strathfieldsaye. (Zone of *Didymograptus nodosus*).
167. 21 chains east of Allot. 30, Sect. III., Strathfieldsaye (on road). (Zone of *Didymograptus nodosus*).
169. Across north-east corner of Allot. 26, Sect. III., Strathfieldsaye. (Outcrops on both roads) (D2—high).
170. Near north-east corner of Allot. 4, Sect. V., Strathfieldsaye (on east and west road—very limited outcrop). (Zone of *Diplograptus intersitus*).
173. On race at north-east corner of Allot. 1A, Sect. V., Strathfieldsaye. (Zone of *Diplograptus intersitus*).
176. On Sedgwick-road about half-way between water-race and the south-west corner of Allot. 4, Sect. V., Strathfieldsaye. (Zone of *Didymograptus nodosus*—low).
179. At south-west corner of Parish of Strathfieldsaye (B2).
- 180, 181. Near loc. 179.
196. 1 chain east from north corner of Allot. 3, Sect. XIX., Strathfieldsaye (an extensive surfaced area). (Zone of *Diplograptus intersitus*).
197. 10 chains east from Loc. 196. (Zone of *Didymograptus nodosus*—low).
198. On south side of road north of Allot. 8, Sect. VI., Strathfieldsaye, and just east of Axe Creek (D2).
201. 13 chains north, 8 chains west from south-east corner of Allot. 2A, Sect. V., Strathfieldsaye (in bed of watercourse). (Zone of *Diplograptus intersitus*).
202. In water-course in north-east corner of Allot. 27, Sect. III., Strathfieldsaye. (Zone of *Diplograptus intersitus*).
203. On small water-race in centre of same allotment as loc. 202. (Zone of *Diplograptus intersitus*).
205. On road south of Allot. 3A, Sect. VIII., Strathfieldsaye (D4-D5).
209. McIvor-road at south-east corner of Parish of Sandhurst. (Zone of *Didymograptus nodosus*—low).
- 210-211. In storm-water channel on south side of McIvor-road, between loc. 209 and railway crossing at 97 miles 36 chains. (Zone of *Diplograptus intersitus*).
226. On Axe Creek in Allot. 3, Sect. XVI., Strathfieldsaye (C2).
229. On Axe Creek in south-west of same allotment as loc. 226 (C1).
230. At north-west corner of Allot. 9, Sect. XIX., Strathfieldsaye (on road) (L3).
244. In north of Allot. 41, Township of Strathfieldsaye (on water-race—badly cleaved material) (D2).
- 283, 284, 285. In road cutting west of Axe Creek, south-east of Sect. V., Sedgwick. (Zone of *Diplograptus intersitus*).
- 298-299. In watercourse 9 and 19 chains north respectively from the north-west corner of Allot. 1, Sect. IX., Sedgwick. (Zone of *Diplograptus intersitus*).

300. At north-east corner of dam in north-west corner of Allot. 1A, Sect. V., Sedgwick (just off Sedgwick-road). (Zone of *Didymograptus nodosus*).
303. On right bank of Axe Creek in south-west of Allot. 7, Sect. X., Sedgwick. (Zone of *Didymograptus nodosus*—probably).
309. 7 chains west from south-east corner of Allot. 8, Sect. X., Sedgwick. (Zone of *Diplograptus intersitus*—low, or D2 high).
310. 9 chains south, 13 chains west from north-east corner of Allot. 2, Sect. XI., Sedgwick (in tributary water-course) (D2).
313. 3 chains south, 3 chains west from north-east corner of Allot. 6, Sect. X., Sedgwick (on road). (Zone of *Diplograptus intersitus*—low).
314. In small watercourse in north of Allot. 2A, Sect. VIII., Sedgwick (D2).
316. 1 chain north from south-east corner of Sect. XI., Sedgwick (just south of dam) (D5).
325. 1 chain north, 3½ chains east from north-east corner of Allot. 1, Sect. XVII., Sedgwick. (Zone of *Diplograptus intersitus*).

XV. References.

1. HARRIS, W. J. *Proc. Roy. Soc. Vic.* (n.s.), xlv. (2), 1934.
2. WHITELAW, H. S. *Monthly Prog. Rept. Geol. Surv. Vic.* No. 10, 1900.
3. HARRIS, W. J. *Proc. Roy. Soc. Vic.* (n.s.), xxix. (1), 1916.
4. RIPPER, E. A. *Ibid.* (n.s.), xlv. (2), 1932.
5. HARRIS, W. J. *Ibid.* (n.s.), xlv. (1), 1933.
6. HALL, T. S. *Rec. Geol. Surv. Vic.*, iii. (3), 1914, p. 290 et seq.
7. FENNER, C. A. *Proc. Roy. Soc. Vic.* (n.s.), xxxi. (1), 1918, p. 248, &c.
8. STIRLING, J. *Prog. Rept. Geol. Surv. Vic.*, No. IX., 1898.
9. HUNTER, S. Deep Leads of Victoria. *Mém. Geol. Surv. Vic.*, No. 7, 1909, p. 93. (The plates and maps in Memoir No. 7 are in error headed "Memoir No. 6.")
10. KEBLE, R. A., and BENSON, W. N., *Trans. N.Z. Inst.*, lix., 1928.
11. THOMAS, D. E., and KEBLE, R. A. *Proc. Roy. Soc. Vic.* (n.s.), xlv. (2), 1933, p. 40.
12. HALL, T. S. *Geol. Mag.*, Dec. IV., vi., 1899.
13. HALL, T. S. *Proc. Roy. Soc. Vic.* (n.s.), vii., 1894.
14. ELLES, G. L. *Encyc. Brit.* (14th Edition), Vol. XVI., 1929, p. 871.
15. HERMAN, H. *Bull. Geol. Surv. Vic.*, No. 47, 1923.